Climosequence Study of the Mountainous Soils Adjacent to Santa Fe, New Mexico

Owen Carleton Lewis Young Carl Taylor

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Introduction

This study was initiated to gain basic information relating to the climosequence that exists in the southern portion of the Sangre de Cristo Mountains near Santa Fe, New Mexico. Information has been grouped into three logical categories: (1) soil temperature, (2) soil moisture, and (3) management implications.

A prime objective was the determination of the relationship between soil temperature and soil moisture regimes (as defined in the SOIL TAXONOMY) with potential natural vegetation. A secondary objective was the management implications that are related to the separating criteria of the SOIL TAXONOMY through examination of soil genesis and morphology.

Throughout the study the separating criteria delineated in the SOIL TAXONOMY provided the basis for the classification of the involved soils. The obtained information may be considered supplemental to the SOIL TAXONOMY and giving an added dimension to its usefulness. It is directly beneficial to anyone using the hierarchical system of classification.

Measurements used in the study were simple and easily obtained by field test procedures (i.e., soil temperature through the use of thermistors; percent base saturation through the use of a Hach Soils Analysis Kit, Model SA-2). In fact, all measurements were obtained through field, rather than laboratory procedures.

It was postulated that this study should:

1. Allow prediction of soil moisture and soil temperature regimes through correlation of these two factors with potential natural vegetation.
2. Reduce the problem of collecting climatic data.
3. Determine the modifying influences of aspect and elevation on the climate associated with particular soils.
4. Where feasible, show the effect of an interruption of climax vegetation and its influence on soil temperature/moisture regimes.
5. Have potential management practice implications relating directly to products and environment.
6. Provide data to be used to classify the soils within the study area.
7. Provide a basis for consistent recognition of soil moisture/temperature regimes within Region Three.

Design of Study

The first part of this study deals primarily with the correlation of soil moisture/temperature regimes with potential natural vegetation. Specific objectives related to each of the following soil temperature sites are:

Site 1	Measure the temperature of the Penitente soils and correlate with the Alpine Tundra.
Site 2	Measure the temperature of the Penitente soils in the transition (Krummholz) zone from Alpine to Engelmann Spruce-Fir Forest.
Site 35	Measure the temperature of the Nambe soils at their upper elevational range and correlate to the Engelmann Spruce-Fir Forest.
Sites 3 and 4	Measure the effect of the absence of overstory on the temperatures of Nambe soils Provide a comparison between soil temperatures for northerly vs. southerly aspects at a fixed elevation.
Sites 5, 7 and 9	Measure and compare temperatures of Nambe soils on northerly vs. westerly vs. southerly aspects at a fixed elevation; study the correlation between soil temperatures and the Engelmann Spruce-Fir Forest. Site is considered representative of the lower elevational limit on southern aspects of the Engelmann Spruce-Fir Forest.
Site 17	Measure the temperature of Nambe soils on a northerly aspect that is considered representative of the lower elevational limits of the Engelmann Spruce-Fir Forest.
Sites 13, 14 and 24	Measure temperature of soils associated with the Douglas Fir-Engelmann Spruce Forest under a seral stage of vegetative development (aspen-forb-grass community). Differences among southerly vs. westerly vs. northerly aspects were considered.
Sites 25, 27 and 29	Measure temperatures of Medio soils within the Douglas Fir-Engelmann Spruce Forest.
Sites 22 and 36	Measure temperatures of Hyde soils associated with the Douglas Fir-Ponderosa Pine Forest in a seral stage of vegetative development (aspen-forb-grass). Elevational range was selected to determine the influences of upper and lower elevations on southerly slopes.
Sites 12 and 16	Measure temperatures of Hyde soils and their correlation with the Douglas Fir-Ponderosa Pine Forest. Aspects and elevational ranges were selected to set the temperature range of this potential natural vegetation separate.
Sites 10 and 11	Measure temperatures of soils (Site 10) within the lower elevational limits of the Douglas Fir-Ponderosa Pine Forest. Also of interest was the comparison (Sites 10 and 11) of a fixed elevation and steep (60-70%) slopes of northerly vs. southerly aspects on soil temperature regimes. Site 10 is associated with the Douglas Fir-Ponderosa Pine Forest; site 11 with the Pinyon-Juniper Woodland.
Sites 8, 19 and 20	Measure the temperatures of the Mirabal soils and their correlation with the Ponderosa Pine Forest. Also of interest was the establishment of an elevational range for the Ponderosa Pine Forest and its correlation with soil temperatures.
Sites 5, 11 and 21	Correlate the temperatures of Chimayo soils with the Pinyon-Juniper Woodland.
Site 18	Measure the effect of a northerly aspect on soil temperatures within the Pinyon-Juniper Woodland.
Sites 26 and 30	Correlate the temperature of Quintana soils with the Juniper-Pinyon Woodland; the effect of northerly vs. southerly aspects at a fixed elevation.

Procedures

Moisture and temperature parameters are among the most practical and reliable approaches for recognizing physical range of potential natural vegetation. The correlation of soil temperature and soil moisture regimes should be valid wherever this potential natural vegetation is identified in Region Three. The soil moisture/temperature regimes conform to the definitions given in the SOIL TAXONOMY.

Soil temperature regimes are relatively simple to determine. The procedure and equipment for measuring is explained in U.S. Forest Service Research Note RM-80. Representative temperature sites were located in well defined potential natural vegetative communities that can be managed as separate entities. Seven potential natural vegetative communities were recognized in the study along with several seral communities.

Determination of the soil moisture regimes for skeletal mountain soils is somewhat difficult. The dearth of climatic data and the physical difficulty of obtaining soil moisture measurements in skeletal soils seriously hamper the researcher. Although no attempt was made to measure the moisture regimes in the field, it is reasonable to assume from available data that:

1. The Douglas Fir-Engelmann Spruce Forest, Douglas Fir-Ponderosa Pine Forest, Spruce-Fir Forest, and Alpine are under an environment where the moisture control section of the associated soils is not dry as long as 90 cumulative days. This is basically the definition of the udic moisture regime given in the SOIL TAXONOMY.
2. The Juniper-Pinyon Woodland, Pinyon-Juniper Woodland, and Ponderosa Pine Forest best fit an environment where the probability of moisture within the moisture control section would be limiting, but moisture would be present when conditions are suitable for plant growth. This is basically the definition of an ustic moisture regime given in the SOIL TAXONOMY.

These assumptions are supported later in this paper.

A soil survey (SOIL RESOURCE INVENTORY OF THE TESUQUE RANGER DISTRICT) of the study area was completed in 1973. The soils were tentatively classified according to the SOIL TAXONOMY and further identified at the series level. Table 1 shows the general relationship between the soil series and important correlative characteristics. Included in Table 1 are ranges in elevation, annual precipitation, soil depth, geology, and several additional significant characteristics.

An examination of climatological data for the northern mountains of New Mexico indicates the annual departure from normal for the study period through December 1973 is a *minus 0.7°F* for temperature and a *minus 1.73 inches* for precipitation. These deviations are based on records from 1931 through 1960.

It is felt that the study period approximates a normal year so that the level of confidence given to this study is equivalent to a long term study (20 years) This allows a higher degree of reliability for the study without actual long term records of soil temperature and moisture.

Table 2 identifies specific study sites and major characteristics of these sites. A discussion of how this information relates to the major modifiers of soil climate and characteristic overstory vegetation is presented in the Results and Discussion section of this paper. Measurements of snow accumulation were taken each month allowing a study of the insulation effect of snow on soil temperature.

Table 1 - Soils and Major Associated Evaluative Characteristics

Soil Series	Potential Natural Vegetation	Soil Temp. Regime	Soil Mois. Regime	Elevational Range (feet)	Annual Precip. (inches)	Soil Depth to R (inches)	Geology	Additional Significant Characteristics
Penitente	Alpine	Pergelic	Udic	11,500-13,160	30-40+	60+	Granite	Well expressed cambic and Bir
Nambe	Spruce-Fir Forest	Cryic	Udic	10,000-12,000	25-40	60+	Granite	Well expressed cambic and Bir
Medio	Douglas Fir-Engelmann Spruce Forest	Cryic	Udic	9,000-10,500	25-35	60+	Granite	Well expressed cambic
Hyde	Douglas Fir-Ponderosa Pine Forest	Frigid	Udic	8,000-9,500	20-30	60+	Granite	Weakly expressed cambic
Mirabal	Ponderosa Pine Forest	Frigid	Ustic	7,500-9,500	18-20	20-40	Granite	-
Chimayo	Pinyon-Juniper Woodland	Mesic	Ustic	7,000-8,500	12-20	10-20	Granite	-
Laguna	Pinyon-Juniper Woodland	Mesic	Ustic	7,000-8,500	12-20	60+	Pennsylvanian Rocks, Undivided	-
Quintana	Juniper-Pinyon Woodland	Mesic	Ustic	6,000-7,000	12-16	60+	Santa Fe Group, Undivided	

Penitente - Pergelic Cryumbrept, loamy-skeletal, mixed
Nambe - Dystric Cryochrept, loamy-skeletal, mixed
Medio* - Dystric Cryochrept, loamy-skeletal, mixed
Hyde* - Typic Dystrochrept, loamy-skeletal, mixed, frigid
Mirabal - Typic Ustorthent, loamy-skeletal, mixed, nonacid, frigid
Chimayo - Lithic Ustorthent, loamy-skeletal, mixed, nonacid, mesic
Laguna* - Ustollic Calciorthid, loamy-skeletal, mixed, mesic
Quintana* - Ustochreptic Calciorthid, fine-loamy, mixed, mesic

*Proposed Series

TABLE 2. SEVERAL MAJOR INFLUENCING CHARACTERISTICS OF SOIL TEMPERATURE SITES

Soil Series	Site No.	Elevation (feet)	Aspect (Deg.)	Litter (in.)	Slope (%)	Surface Coarse Fragments (2 mm) (%)	Depth of Temperature Measurement (in.)	Composition of Major Trees: Canopy Cover (%)	Engelmann Spruce (%)	Alpine Firs (%)	White Fir (%)	Douglas Fir (%)	Quaking Aspen (%)	Ponderosa Pine (%)	Pinyon Pine (%)	One-seed Juniper (%)	Potential Natural Vegetation
Penitente	1	12,130	262	0	35	75	20	0	0	0	0	0	0	0	0	0	Alpine
Penitente	2	12,120	152	0	25	50	20	0	5	0	0	0	0	0	0	0	Alpine (Krummholz
Nambe	35	11,700	242	C-1	29	-	20	85	95	5	0	0	0	0	0	0	Spruce-Fir Forest
Nambe, eroded	3	11,240	317	0	32	20	20	0	0	0	0	0	0	0	0	0	Spruce-Fir Forest (Burn -Seral) (Grass & Forb)
Nambe, eroded	4	11,230	177	0	33	25	20	0	0	0	0	0	0	0	0	0	Spruce-Fir Forest (Burn - Seral) (Grass & Forb)
Nambe	9	11,000	312	C-1	43	-	20	80	95	5	0	0	0	0	0	0	Spruce-Fir Forest
Nambe	5	10,990	272	C-1	41	-	20	80	95	5	0	0	0	0	0	0	Spruce-Fir Forest
Nambe	7	10,930	252	C-1	39	-	20	75	95	5	0	0	0	0	0	0	Spruce-Fir Forest
Nambe	17	10,022	327	C-2	39	-	20	80	40	40	0	0	20	0	0	0	Spruce-Fir Forest
Medio	14	10,400	192	C-2	53	-	20	90	0	0	0	0	100	0	0	0	Douglas Fir-Engelmann Spruce Forest (Burn - Seral) (Aspen-Forb-Grass)
Medio	13	10,440	257	C-2	35	-	20	90	0	0	0	0	100	0	0	0	Douglas Fir-Engelmann Spruce Forest (Burn - Seral) (Aspen-Forb-Grass)
Medio	24	10,040	267	C-2	30	-	20	50	0	0	0	30	70	0	0	0	Douglas Fir-Engelmann Spruce Forest (Burn - Seral) (Aspen-Grass-Forb)
Medio	29	9,700	242	C-2	45	-	20	75	40	40	0	0	20	0	0	0	Douglas Fir-Engelmann Spruce Forest
Medio	27	9,660	2	C-1	43	10	20	50	0	0	0	60	40	0	0	0	Douglas Fir-Engelmann Spruce Forest
Medio	25	9,320	337	C-1	48	-	20	75	0	0	20	70	10	0	0	0	Douglas Fir-Engelmann Spruce Forest
Hyde	22	10,000	177	C-1	42	10	20	40	0	0	0	0	100	0	0	0	Douglas Fir-Ponderosa Pine Forest (Burn - Seral) (Aspen-Forb-Grass)
Hyde	36	9,710	197	C-1	45	5	20	30	0	0	0	0	100	0	0	0	Douglas Fir-Ponderosa Pine Forest (Burn - Seral) (Aspen-Forb-Grass)
Hyde	12	9,290	257	C-1	47	10	20	50	0	0	30	50	15	5	0	0	Douglas Fir-Ponderosa Pine Forest
Hyde	16	8,300	312	P-1	55	5	20	50	0	0	20	70	5	5	0	0	Douglas Fir-Ponderosa Pine Forest
Hyde	10	7,860	307	P-1	70	-	20	50	0	0	0	80	0	20	0	0	Douglas Fir-Ponderosa Pine Forest
Mirabal	8	9,300	167	C-1	45	-	20	30	0	0	0	0	0	100	0	0	Ponderosa Pine Forest
Mirabal	19	8,300	177	P-1	60	60	20	45	0	0	0	0	0	100	0	0	Ponderosa Pine Forest
Mirabal	20	7,980	302	C-1	65	-	20	50	0	0	0	5	0	95	0	0	Ponderosa Pine Forest
Chimayo	21	7,980	127	0	65	70	16	40	0	0	0	0	0	S	70	30	Pinyon-Juniper Woodland
Chimayo	11	7,870	157	0	68	80	18	35	0	0	0	0	0	S	60	40	Pinyon-Juniper Woodland
Laguna	18	7,640	325	0	38	40	20	50	0	0	0	0	0	S	70	30	Pinyon-Juniper Woodland
Chimayo	15	7,720	155	0	45	80	16	20	0	0	0	0	0	S	50	50	Pinyon-Juniper Woodland
Quintana	30	7,320	325	0	25	80	20	30	0	0	0	0	0	0	30	70	Juniper-Pinyon Woodland
Quintana	26	7,340	140	0	28	80	20	30	0	0	0	0	0	0	30	70	Juniper-Pinyon Woodland

C - Continuous litter layer
P - Patchy litter layer
S - Widely scattered

Results and Discussion

As previously stated, the information from this study is grouped into one of three categories: (1) soil temperature, (2) soil moisture, and (3) management implications. Table 3 is a summary of soil temperature measurements and the soil temperature regime associated with each site. Soil temperature data for selected sites is plotted in Figures 1 and 2 to express the sequential association and grouping with potential natural vegetation.

Soil Temperatures

Penitente soils at Site 1 are pergelic; the temperature sites selected for the Penitente soils represent the lower elevational limits and southern extent of these soils. Most Penitente soils are at higher elevations and/or northerly aspects making them significantly colder.

Penitente soils at Site 2 are associated with Alpine Tundra transitional to the Engelmann Spruce-Fir Forest (Krummholz). Exposed southerly aspects are significantly warmer than the westerly slopes within the alpine zone (Site 1 vs. Site 2).

Prevailing westerly winds strongly affect the climate of these two sites. Snow accumulation is erratic and usually blown from these slopes. Therefore, little insulation effect can be related to snow cover here.

Soil temperature Sites 5, 7, 9, 17, and 35 relate soil temperatures to the Engelmann Spruce-Fir Forest. The soil temperature regime as determined by this study is cryic. Data for Sites 35 and 17 give an indication of soil temperatures between the upper and lower elevational range of the Nambe soils. This also coincides with the approximate lower and upper elevational range for the Engelmann Spruce-Fir Forest within the study area.

Site No.	Soil Series	Elev. (feet)	Average Summer Soil Temp. °F	Average Yearly Soil Temp. °F	Aspect
35	Nambe	11,700	37	34	W
17	Nambe	10,022	40	35	NW

Aspen is present at Site 17 and is indicative of a transitional zone to a Douglas Fir-Engelmann Spruce Forest. Aspen are not adaptable to the well-defined Engelmann Spruce-Fir Forest; therefore, under the typical situation they are absent. Further examination of the soil temperatures of Sites 35 and 17 shows they are roughly the same (34°F vs 35°F) despite an elevational difference of approximately 1,700 feet.

Sites 3 and 4 are in an old (late 1890's) burn. Site 3 is on a northerly aspect and is windswept most of the winter months with little snow accumulation, whereas snow tends to accumulate on the southerly aspects at Site 4 (Table 4). There has been little or no Engelmann Spruce regeneration to date on the Nambe soils (Table 2). Average summer soil temperatures of Sites 3 and 4 are within the range for normal Nambe soils. Average yearly soil temperatures at Site 3 indicate the soil approaches a pergelic soil temperature regime. Comparison of soil temperatures at Sites 5, 7, and 9 with those for Sites 3 and 4 indicates little difference between average summer soil temperatures. It is apparent that soil temperatures at Site 3 drop at a faster rate in October and November than normal Nambe soils. Conversely at Site 4 soil temperatures remain warmer during these months than normal Nambe soils. These shifts in soil

TABLE 3. SOIL TEMPERATURES - JUNE 1973 THROUGH MAY 1974

Soil Series	Site No.	June 1973	July 1973	Aug. 1973	Sept. 1973	Oct. 1973	Nov. 1973	Dec. 1973	Jan. 1974	Feb. 1974	Mar. 1974	Apr. 1974	May 1974	Avg. of June, July, August	Avg. Yearly	Soil Temp. Regime
Penitente	1	35.0	41.6	42.7	40.1	34.0	30.4	26.0	20.2	18.6	23.0	24.6	32.3	39.8	30.7	Pergelic
Penitente	2	38.7	44.3	45.5	44.7	37.2	33.9	30.5	23.8	23.1	27.4	27.9	34.4	42.8	34.2	Cryic
Nambe	35	34.0	36.0	40.5	40.1	36.2	32.9	32.0	30.9	30.7	30.3	30.5	31.2	36.8	33.8	Cryic
Nambe, eroded	3	35.6*	41.5	43.3	41.9	35.4	32.0	27.7	26.3	21.0	23.6	25.9	30.7	40.1	32.1	Cryic
Nambe, eroded	4	35.0	41.7	47.3	48.1	40.7	37.2	33.9	32.9	32.4*	32.0	32.7	32.2	41.3	37.3	Cryic
Nambe	9	32.0	39.9	41.3	39.1	37.9	32.7	31.8	30.7	30.6	30.5	31.2	31.2	37.7	34.1	Cryic
Nambe	5	32.9	41.3	43.1	42.6	42.3	36.6	33.1	31.2	30.9	30.7	31.2	32.0	39.1	35.7	Cryic
Nambe	7	38.1	44.7	46.9	46.3	40.5	36.2	32.7	30.5	29.8	30.5	31.4	37.5	43.2	37.1	Cryic
Nambe	17	35.6	43.0	44.5	42.8	37.9	33.1	31.8	30.5	29.6	30.3	30.5	34.8	41.0	35.4	Cryic
Medio	14	43.9	46.9	47.9	47.7	41.9	40.1	34.6	33.3	33.9	33.1	34.6	43.0	46.2	40.1	Cryic
Medio	13	39.7	43.9	45.3	44.5	38.7	36.6	33.1	32.2	31.6	31.6	31.8	36.2	43.0	37.1	Cryic
Medio	24	41.5	44.9	44.5	45.1	40.3	36.4	34.8	33.3	32.7	32.7	33.1	39.6	43.6	38.2	Cryic
Medio	29	38.7	44.1*	45.5	43.1	38.1	33.9	32.4	31.4	30.9	31.2	31.6	35.8	42.8	36.4	Cryic
Medio	27	41.7	45.5	47.7	45.1	40.1	35.8	33.9	32.4	31.8	33.1	32.2	38.9	45.0	38.2	Cryic
Medio	25	41.7	47.3	48.7	47.3	41.3	37.7	35.0	32.7	31.6	32.7	32.9	40.5	45.9	39.1	Cryic
Hyde	22	49.3*	51.4	52.7	52.4	47.1	45.5	37.9	35.6	33.5	34.6	38.5	49.1	51.1	44.0	Frigid
Hyde	36	45.0*	48.1	50.2	49.6	43.3	41.3	36.2	34.6	33.9	33.9	36.6	44.9	47.7	41.5	Frigid
Hyde	12	48.5	50.0	51.2	49.3	43.3	39.7	36.8	34.4	33.3	33.1	33.3	43.0	49.9	41.3	Frigid
Hyde	16	45.7	49.5	51.0	48.3	40.9	36.6	34.4	33.5	31.6	32.4	34.4	49.9	48.7	40.7	Frigid
Hyde	10	49.1	54.6	57.0	52.2	44.1	40.7	33.9	32.9	29.4	32.2	35.8	47.9	53.7	42.5	Frigid
Mirabal	8	45.7	50.6	52.0	52.2	47.3	46.1	39.6	35.0	33.9	35.6	38.1	46.1	49.4	43.5	Frigid
Mirabal	19	53.7	56.4	58.1	57.4	49.3	47.7	38.7	34.4	33.9	37.2	40.1	54.3	56.1	46.8	Frigid
Mirabal	20	46.9	52.2	53.1	49.5	43.0	38.7	36.0	34.4	30.9	32.9	34.6	44.1	50.7	41.4	Frigid
Chimayo	21	58.9	61.4	64.8	61.4	51.0	48.1	37.9	35.6	33.9	39.1	43.7	57.1	61.7	49.4	Mesic
Chimayo	11	58.3	61.2	65.6	62.7	56.4	54.3	44.9	40.3	38.1	41.7	44.7	58.1	61.7	52.2	Mesic
Laguna	18	52.9	57.4	59.3	52.9	43.7	37.0	34.4	32.0	29.7	32.4	36.4	50.4	56.5	43.2	Frigid
Chimayo	15	61.4	63.1	67.3	63.7	54.7	51.8	42.8	36.4	36.6	40.9	46.3	61.0	63.9	52.2	Mesic
Quintana	30	67.0	68.7	71.2	65.6	51.4	42.6	34.8	33.9	30.7	35.8	45.9	64.8	69.0	51.0	Mesic
Quintana	26	67.3	69.6	72.9	70.0	61.4	56.2	46.1	38.1	39.9	45.1	51.2	65.6	69.9	57.0	Mesic

Measurements taken around 15th of each month.
* Missing data - removed from graph of temperature vs. time.

TABLE 4. SNOW DEPTH MEASUREMENTS AT SOIL TEMPERATURE SITES

Soil Series	Site No.	June 1973	July 1973	Aug. 1973	Sept. 1973	Oct. 1973	Nov. 1973	Dec. 1973	Jan. 1974	Feb. 1974	Mar. 1974	Apr. 1974	May 1974
							(inches)						
Penitente	1	0	0	0	0	1	1	1	P-1	2	1	3	0
Penitente	2	0	0	0	0	36	1	1	P-1	2	0	2	0
Nambe	35	P	P	0	0	7	1	12	30	48	36	30	3
Nambe, eroded	3	0	0	0	0	5	1	1	12	48	1	2	0
Nambe, eroded	4	180	0	0	0	0	1	24	60	66	66	66	10
Nambe	9	0	0	0	0	6	1	12	24	28	30	30	4
Nambe	5	0	0	0	0	6	1	1	30	36	30	24	6
Nambe	7	0	0	0	0	0	1	8	18	24	18	8	0
Nambe	17	0	0	0	0	2	1	0	18	24	30	18	0
Medio	14	0	0	0	0	0	P-1	0	15	18	36	0	0
Medio	13	0	0	0	0	P-1	1	0	24	36	30	18	0
Medio	24	0	0	0	0	1	P-1	0	18	24	18	5	P-2
Medio	29	0	0	0	0	2	P-1	0	20	30	20	18	0
Medio	27	0	0	0	0	1	P-1	0	16	16	18	18	0
Medio	25	0	0	0	0	P-1	P-1	0	8	12	8	0	0
Hyde	22	0	0	0	0	0	P-1	0	10	5	0	0	0
Hyde	36	0	0	0	0	0	P-1	0	12	8	1	0	0
Hyde	12	0	0	0	0	P-1	P-1	0	10	12	8	0	0
Hyde	16	0	0	0	0	P-1	P-1	0	8	12	0	0	0
Hyde	10	0	0	0	0	P-1	P-1	0	P-5	2	0	0	0
Mirabal	8	0	0	0	0	P-1	P-1	0	2	1	0	0	0
Mirabal	19	0	0	0	0	P-1	P-1	0	2	1	0	0	0
Mirabal	20	0	0	0	0	P-1	P-1	0	8	3	0	0	0
Chimayo	21	0	0	0	0	P-1	P-1	0	P-2	1	0	0	0
Chimayo	11	0	0	0	0	P-1	P-1	0	0	0	0	0	0
Chimayo	18	0	0	0	0	P-1	P-1	0	P-1	7	4	0	0
Laguna	15	0	0	0	0	P-1	P-1	0	0	0	0	0	0
Quintana	30	0	0	0	0	0	P-1	0	P-7	P-12	0	0	0
Quintana	26	0	0	0	0	0	P-1	0	P-1	0	0	0	0

P - Patchy

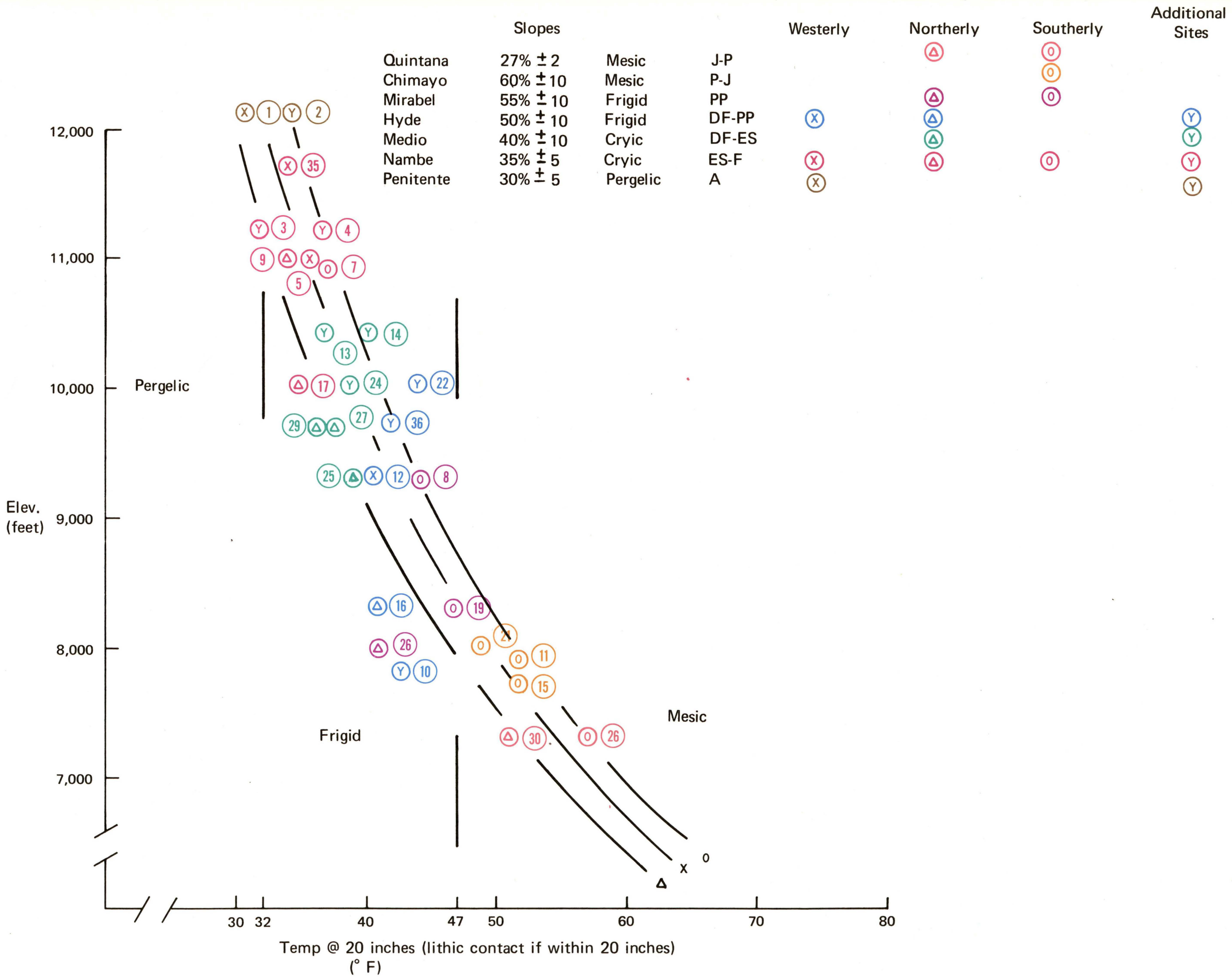


Figure 1. Plot of Average Yearly Soil Temperature vs. Elevation

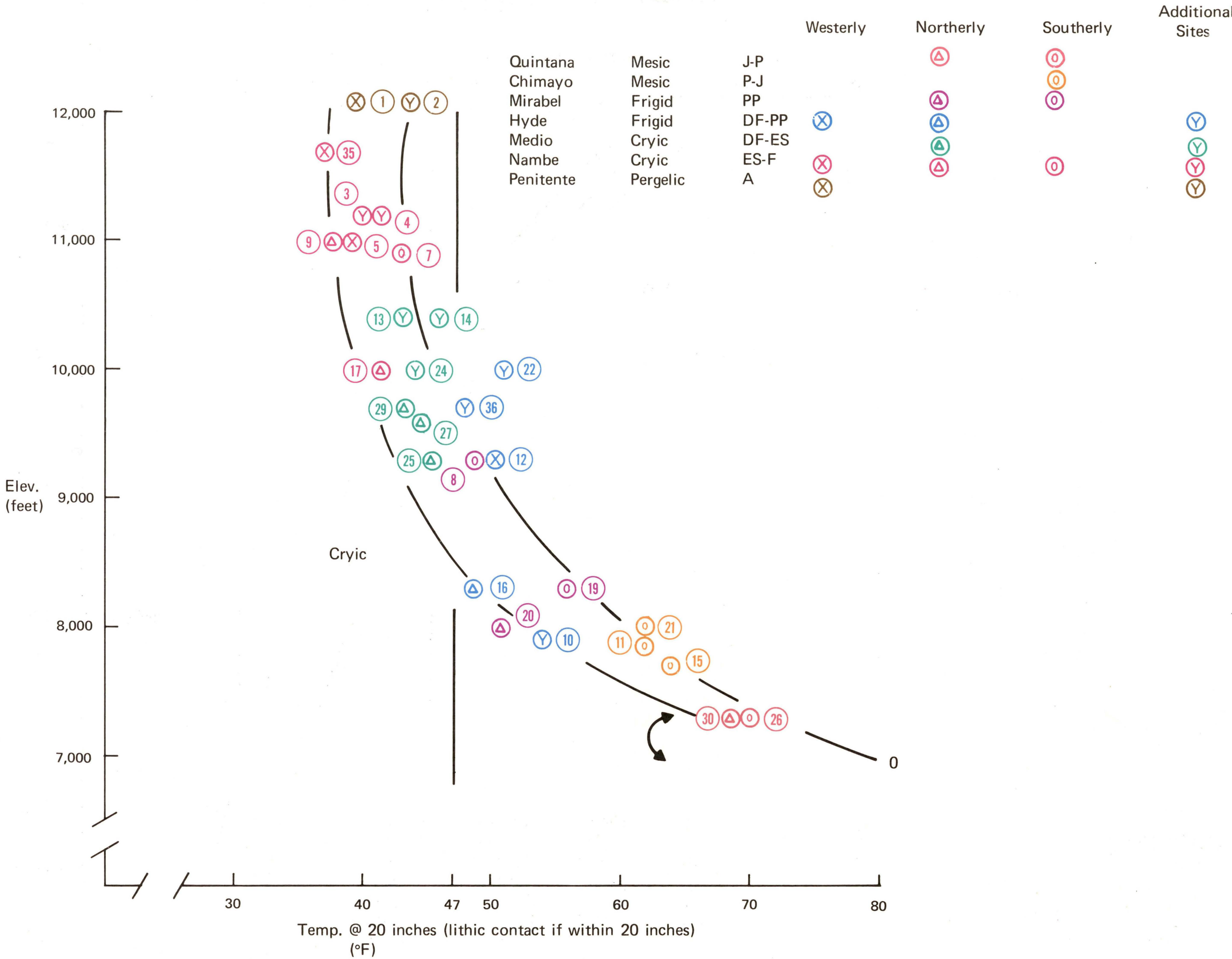


Figure 2. Plot of Average Summer (June, July, August) Soil Temperature vs. Elevation

temperatures are attributed to lack of vegetative overstory or snow cover and their modifying effect on soil temperatures during those periods.

Data for Sites 5, 7, and 9 show the influence of aspect on soil temperatures within the Engelmann Spruce-Fir Forest.

Site No.	Soil Series	Elev. (feet)	Average Summer °F	Average Yearly °F	Aspect
9	Nambe	11,000	38	34	NW
5	Nambe	10,990	39	36	W
7	Nambe	10,930	43	37	SW

Average summer soil temperatures are about the same for northerly and westerly aspects while the southerly aspects are warmer. Average yearly soil temperatures show only a 3°F range. Site 5 is representative of the lower elevational extent of the Engelmann-Spruce-Fir Forest and Nambe soils on southerly aspects.

Medio soils have a cryic soil temperature regime and are associated with the Douglas Fir-Engelmann Spruce Forest. Sites 25, 27, and 29 have vegetation typical of the Douglas Fir-Engelmann Spruce Forest while the vegetation at Sites 13, 14, and 24 is indicative of a seral stage. The present vegetation at these latter three sites is resultant from the same fire associated with Sites 3 and 4. This seral vegetation is characterized by dense stands of aspen with a sparse understory of grasses and forbs.

Examination of the soil temperature data from these six sites shows little difference among them. This indicates the seral vegetation is modifying soil temperatures in a similar manner to that of the potential natural vegetation.

Soil Series	Site No.	Avg. Summer Soil Temp. °F	Avg. Yearly Soil Temp. °F	Potential Natural Vegetation
Nambe	35	37	34	Engelmann Spruce-Fir Forest
Nambe	9	38	34	Engelmann Spruce-Fir Forest
Nambe	5	39	36	Engelmann Spruce-Fir Forest
Nambe	17	41	35	Engelmann Spruce-Fir Forest
Medio	27	45	38	Douglas Fir-Engelmann Spruce Forest
Medio	25	45	39	Douglas Fir-Engelmann Spruce Forest
Medio	29	43	36	Douglas Fir-Engelmann Spruce Forest

Even though both the Nambe and Medio soils are cryic, there is a separating difference between average summer and a slight difference in yearly soil temperatures of Nambe vs. Medio soils. This temperature differential is significant enough to separate two main potential natural vegetative communities (Engelmann Spruce-Fir Forest vs. Douglas Fir-Engelmann Spruce Forest).

Hyde soils (Sites 10, 12, 16, 22, and 36) Mirabal soils (Sites 8, 19, and 20) are in a frigid and soil temperature regime. The following is a comparison of soil temperatures for these soils.

Soil Series	Site No.	Avg. Summer Soil Temp. °F	Avg. Yearly Soil Temp. °F	Potential Natural Vegetation
Hyde	22	50	44	Douglas Fir-Ponderosa Pine Forest (Burn-Seral) (Aspen-Forbs-Grass)
Hyde	36	48	42	Douglas Fir-Ponderosa Pine Forest (Burn-Seral) (Aspen-Forbs-Grass)
Hyde	12	50	41	Douglas Fir-Ponderosa Pine Forest
Hyde	16	49	41	Douglas Fir-Ponderosa Pine Forest
Hyde	10	54	43	Douglas Fir-Ponderosa Pine Forest
Mirabal	8	49	44	Ponderosa Pine Forest
Mirabal	19	56	47	Ponderosa Pine Forest
Mirabal	20	51	41	Ponderosa Pine Forest

Hyde soils at Sites 24 and 36 are associated with seral vegetation. The present vegetation at these sites results from the same fire associated with Sites 3, 4, 13, 14, and 24. This seral vegetation is characterized by dense stands of aspen with a sparse understory of grasses and forbs. A comparison of the Hyde soil temperatures indicates that the seral vegetation is modifying soil temperatures in a manner similar to that of climax vegetation (Sites 22 and 36 vs. Sites 12 and 16). Although Hyde soils at Sites 12 and 16 are separated by approximately 1,000 feet in elevation, they yield approximately the same soil temperature readings.

Sites 10 and 11 show the influence of opposing steep slopes at lower elevations. Site 10 is in the Hyde soils and Site 11 is in the Chimayo soils. The Hyde soils at Site 10 are frigid while Chimayo soils at Site 11 are mesic. The steep, sourtherly aspects of Site 11 receive a high degree of insolation when compared with the steep northerly aspects of Site 10 which are shaded most of the year.

The Mirabal soils at Sites 8, 19, and 20 are frigid and in the Ponderosa Pine Forest. Sites 8 ad 19 show the influence of elevation on soil temperatures within the Ponderosa Pine Forest. Site 8 is representative of the upper elevational extent on southerly aspects of the Ponderosa Pine Forest. These sites are separated by approximately 1,000 feet in elevation. Average summer soil temperatures differ by 7°F while average yearly soil temperatures differ by only 4°F. Site 20 is representative of the lowest elevational range of the Ponderosa Pine Forest and is confined to a northerly aspect.

Sites 11, 15, and 21 are associated with a mesic soil temperature regime, Chimayo soils, and the Pinyon-Juniper Woodland.

Site 18 is in a transitional area between the Pinyon-Juniper Woodland and the Douglas Fir-Ponderosa Pine Forest. This site is a few miles west of Site 10 and has a similar position on the landscape. The comparison between Sites 10 and 18 is atypical because the Ponderosa Pine Forest which usually occurs between these vegetative associations is missing. Temperature data for Site 18 indicate the site is in a frigid soil temperature regime although vegetatively it appears to be Pinyon-Juniper Woodland. Its importance lies in the recognition of narrow transitional zones; it is not representative of significant areas.

Sites 26 and 30 are associated with Quintana soils, Juniper-Pinyon Woodland and a mesic soil temperature regime. One notes that the Quintana soils (Site 26) on a southerly aspect are approaching the criteria of a thermic soil temperature regime. Average summer soil temperatures are significantly higher for the Quintana soils than for the Chimayo soils.

Figures 1 and 2, combined, show the characteristic grouping of soil temperatures and their correlation with potential natural vegetation. The influence of slope, degree, aspect, and vegetation is reflected in the projected curves.

A comparison of soil temperatures (Table 3) and snow depths (Table 4) reveals the degrees of modifying influence of snow pack on soil temperatures. The insulation effect by snow is most apparent at the higher elevations where snow packs tend to accumulate. Site 4 with its deeper snow cover has significantly warmer winter soil temperatures than Site 3.

Soil Moisture

Since high volumes of coarse fragments (>2 mm) within the soil profile physically limit the measuring of soil moisture, soil moisture regimes were recognized from climatic data, water balance, and/or genesis and morphology.

Climatic data using in setting the parameter limits of potential natural vegetation are usually broad. Examples of this are in Tables 1 and 5. Table 1 lists seven potential natural vegetation communities and significant environmental characteristics that can be related to soil moisture. Table 5 contains similar information regarding the climate associated with four well-defined forest types.

Figure 3 depicts an ustic soil moisture regime associated with the Juniper-Pinyon Woodland at Santa Fe, New Mexico. The site of the climatic data used to generate Figure 3 can be related to soil temperature sites 30 and 26.

The inference from the information in Tables 1 and 5 and Figure 3 is that the Ponderosa Pine Forest becomes the delineator for the ustic soil moisture regime; the Douglas Fir-Ponderosa Pine Forest the delineator for the udic soil moisture regime. The most logical separation between ustic and udic soil moisture regimes should occur between these two forest types.

Douglas fir is the key plant in separating the Ponderosa Pine Forest from the Douglas Fir-Ponderosa Pine Forest. It is known to need a more moist environment than ponderoa pine; therefore, it is a key plant in identifying the drier limit of the udic soil moisture regime. The Ponderosa Pine Forest manifests itself under a moisture condition characterized by a ustic soil moisture regime — mainly dry spring and fall periods. This is not characteristic of the Douglas Fir-Ponderosa Pine Forest.

Since the Douglas Fir-Engelmann Spruce Forest, Engelmann Spruce-Fir Forest, and Alpine are associated with higher moisture requirements than the Douglas Fir-Ponderosa Pine Forest, they are assumed to be in an udic soil moisture regime. It appears that the Engelmann Spruce-Fir Forest may fall within a perudic soil moisture regime.

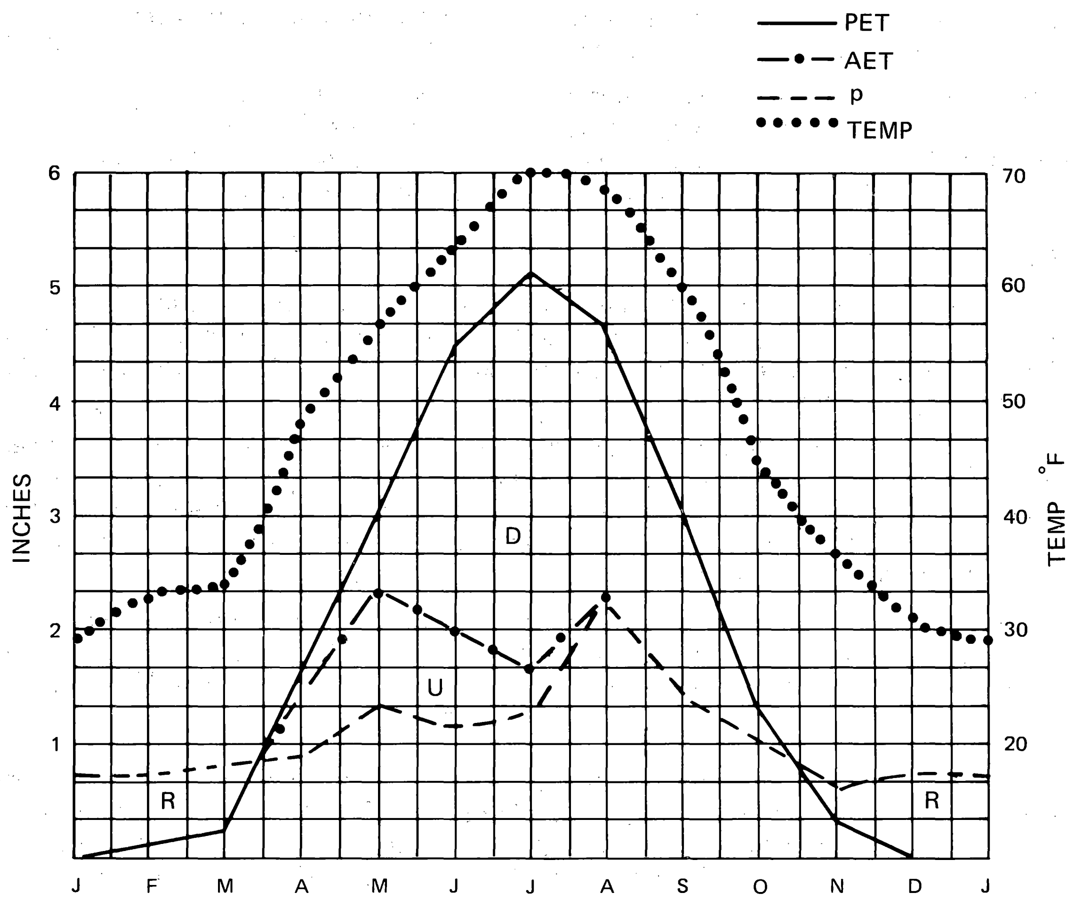
The Pinyon-Juniper Woodland and Juniper-Pinyon Woodland are associated with lower moisture requirements than the Ponderosa Pine Forest. Lower moisture requirements and water balance (Figure 3) indicate these potential natural vegetation separates are in an ustic soil moisture regime.

The soils associated with the Douglas Fir-Ponderosa Pine Forest and Ponderosa Pine Forest give an additional reason for separating these soil moisture regimes. A generic and morphological examination of Hyde soils (found in Douglas Fir-Ponderosa Pine Forest) show that they developed under a higher moisture regime than the Mirabal soils which coincide with the Ponderosa Pine Forest.

Table 5. Selected Environmental Parameters For Four Forest Types

Forest Type	Summer Temperature June (mean)	July, Aug. (mean-maximum)	September (mean soil temperature) @ 12"	Annual Precipitation	Evaporation (total June to Sept.)	Elevation	Frost Free Period
	(°F) *	(°F) *	(°F) *	(inches) *	(inches) *	(feet) *	Days **
Pinyon-Juniper	65-69	79-85	64-75	12-20	30-40	5,000- 7,000	90-205
Ponderosa Pine	59-63	74-80	56-65	18-25	18-26	7,000- 8,000	—
Douglas Fir	56-58	67-74	52-54	22-34	12-16	8,000- 9,500	120-160
Spruce-Fir	50-56	56-68	44-50	27-36	10-13	9,500-11,500	30- 60

* Data from Yearbook of Agriculture 1941, pp. 497.
** Data from Silvics of Forest Trees of the United States, Agriculture Handbook No. 271.



RECHARGE = 2.84″ USE = 2.84″

PRECIP = 12.80″ PET = 23.89″

AET = 12.20″ DEFICIT = 11.09

FIGURE 3. MOISTURE REGIME - SANTA FE, NM. 7200′ ELEV

Of the five major soil forming factors, three can be fixed for these mountain soils: time, topography, and parent material. They are forming on steep slopes from sedentary parent material derived from Pre-Cambrian granite. Organisims and climate can be partially fixed.

Animal influence can be dismissed as negligible; vegetation is the only viable component of organism factor. Vegetative influence can be seen through an examination of potential natural vegetation.

Climate is somewhat fixed by both soils being in a frigid temperature regime. The only climatic variable of significant magnitude that needs to be accounted for is effective precipitation. It is reflected in soil depths and pedogenic horizons.

Mirabal soils have depths of 20 to 40 inches to granite bedrock while Hyde soils have depths over 40 inches. Mirabal soils have no evidence of pedogenic horizons but Hyde soils have a cambic horizon. The implication is that soil genesis of Mirabal soils is related to a drier (ustic) environment while Hyde soils are related to a more moist (udic) environment.

Management Implications

This study reveals a number of related interpretations applicable to both soil survey techniques and land management. A cursory look at information in Table 1 gives an indication of the broad correlation that can be made between soil genesis and morphology as reflected in soil moisture and soil temperature regimes.

Holding parent material source and topography constant and observing the relationship between Chimayo, Mirabal, Hyde, Medio, Nambe, and Penitente soils, there are several apparent conclusions that can be drawn. With an increase in moisture, there is a corresponding increase in soil depth to bedrock (weathering) and the expression of soil development. Increase in moisture is also closely related to an increase in elevation.

Chimayo soils are shallow (less than 20 inches to lithic or paralithic contact) and weakly expressed. They are found at elevations between 7,000 and 8,500 feet. Penitente soils are deep (40"+), have umbric epipedons, and well expressed cambic horizons. (See Table 1.)

A. *Penitente Soils*

Penitente soils are a member of the loamy-skeletal, mixed family of Pergelic Cryumbrepts. These soils have a restrictive cold climate. An average annual soil temperature of less than 30°F implies an extremely short growing season (frost-free period) of approximately 15-30 days. Frost can occur at any time of the year. These soils are in an environment that allows for the development of an umbric epipedon, cambic horizon, Bir horizon, and soil depths of over 40 inches to bedrock.

A base saturation of approximately 30 percent in the umbric epipedon implies a low base saturation. The significance of this lies in the cycling of bases; numerous alpine forbs, sedges, and grasses are an integral part of the cycling process.

The cambic horizon has a base saturation of 10-15 percent. This reflects a high rate of effective precipitation and subsequent leaching.

The potential capacity of these soils to produce vegetative biomass is limited mainly by its cold (pergelic) climate and low base saturation within the subhorizons. Removal of protective vegetation on Penitente soils will result in serious sheet and gully erosion. From a practical point it will be impossible to establish protective vegetation on Penitente soils.

B. *Nambe Soils*

Nambe soils are a member of the loamy-skeletal, mixed family of Dystric Cryochrepts.

These soils have a cold (cryic), wet (udic) climate. The total environment is such that there is a limited range of plants that are adaptable. There is a noticeable absence of aspen within the Engelmann Spruce-Fir Forest. These soils are within an environment that allows for the development of an ochric epipedon, cambic horizon, Bir horizon, and soil depths of over 40 inches to granite bedrock. Base saturation of the 25 cm to 75 cm zone of the soil profile is approximately 5-15 percent. The lack of deciduous trees, cold climate, and high effective precipitation has resulted in an acid condition (pH 3.0-5.0). Under these conditions there is an effective leaching of bases and formation of Bir horizons in the upper portion of the cambic horizon.

The low base saturation associated with these soils is a limiting factor relating to inherent fertility. Establishment of Engelmann spruce seedlings on these soils will prove difficult primarily due to environment. A major contributor to this difficulty is the lack of a nurse crop for these photosensitive plants. Interruption of the Engelmann Spruce-Fir Forest usually results in a seral community of grasses, sedges, and forbs. Natural regeneration usually results from a slow progressive establishment of Engelmann spruce seedlings within the peripheral microclimate afforded by undisturbed Engelmann spruce stands.

C. *Medio Soils*

Medio soils are a member of the loamy-skeletal, mixed family of Dystric Cryochrepts. As the classification implies, these soils are similar to Nambe soils. Medio soils are separate because they have a base saturation of 30-40 percent (25 cm to 75 cm zone) and lack Bir horizons. This implies a less acid environment as well as less effective precipitation with respect to leaching of bases when compared with Nambe soils. Numerous deciduous trees occur within the environment of Medio soils thus contributing to the cycling of bases through seasonal leaf fall and consequent decomposition.

Among the soils of the study area, the Medio soils afford the highest capacity to produce vegetative biomass. Capability to produce this biomass appears to be limited by inherent soil fertility. This inherent restriction on fertility is attributed in part to the characteristic low base saturation of these soils. The greatest *number* and *diversity* of plant species was observed within these soils. Soils, as a whole, associated with this forest type offer the maximum opportunity for intensive vegetative management.

D. *Hyde Soils*

Hyde soils are a member of the loamy-skeletal, mixed, frigid family of Typic Dystrochrepts. These soils have a wet (udic), cool (frigid) climate. Within the 25 cm to 75 cm zone of the soil profile, the base saturation is approximately 40-60 percent. This indicates a lower effective precipitation with correspondingly less leaching of bases as compared to Medio soils. These soils are within an environment that allows for the development of a weak cambic horizon, and soil depths of 40 inches or greater to granite bedrock. Often this cambic horizon is structureless and is based mainly on evidence of alteration with respect to soil colors and textural increase.

Although these soils are within an udic soil moisture regime, they are approaching an ustic soil moisture regime. It is a combination of moisture and soil fertility that limits total production of vegetative biomass within these soils. Hyde soils are a close second to Medio soils in capacity to produce vegetative biomass.

E. *Mirabal Soils*

Mirabal soils are a member of the loamy-skeletal, mixed, nonacid, frigid family of Typic Ustorthents. These soils reflect the decrease in effective moisture over that of Hyde soils in the form of lesser depths to granite bedrock (20-40"). There is little or no evidence of development of pedogenic horizons in Mirabal soils. Soil depth, along with the coarse

fragment content within the soil profile, tends to cause a restricting soil-moisture relationship. There is limited soil moisture storage capacity to assist plants through the dry spring and fall seasons characteristic of the Ponderosa Pine Forest. Potential to produce vegetative biomass is restricted by inherent fertility as well as effective precipitation.

Regeneration of ponderosa pine is most likely limited by soil moisture. This is observed in the uniformity of height of natural regeneration that probably correlates with years of high spring, summer, and fall moisture.

F. *Chimayo Soils*

Chimayo soils are a member of the loamy-skeletal, mixed, nonacid, mesic family of Lithic Ustorthents. These soils reflect an even greater decrease in effective moisture over that of Mirabal soils in the form of shallower depth to granite bedrock (10-20"). The restricting environment (ustic and mesic), along with the parent material source, has resulted in a soil with little or no development of pedogenic horizons.

Chimayo soils are restricted in their potential capacity to produce vegetative biomass by a well expressed combination of limited precipitation and low inherent soil fertility. The low inherent fertility is related to shallow (10-20") soil depths, high amounts of coarse fragments within the soil profile and parent material derived from granite. This leads to a soil with a highly restricted soil-moisture relationship. The soil has low moisture storage capacity and is within an environment that is limited in precipitation. Most often, soils associated with parent materials derived from granite are low in calcium. In addition, the shallow depths and high coarse fragment content within the associated environment tend to restrict root development.

Diversity and number of plant species observed on these soils are measurably less than that of the Mirabal soils. This further indicates a restrictive environment for plants.

G. *Laguna Soils*

Laguna soils are a member of the loamy-skeletal, mixed, mesic family of Ustollic Calciorthids. These soils occur in the same environment (precipitation and temperature) as Chimayo soils. A basic different in these soils can be attributed to parent material source. The highly fractured and interbedded shale and sandstone (Undifferentiated Pennsylvanian Age Formations) are related to the formation of a deep soil (40"+). The better soil-moisture relationship of Laguna soils over that of Chimayo soils is reflected by an increase in organic matter, mainly within the upper six inches of the surface horizons. Characteristically, these soils have a cambic horizon.

Laguna soils are restricted in their potential capacity to produce vegetative biomass because of their limited soil-moisture relationship. The high alkaline-earth content throughout the soil profile tends to cause a physiological drought in some plants. Precipitation is not high enough to significantly offset this effect.

H. *Quintana Soils*

Quintana soils are a member of the loamy-skeletal, mixed, mesic family of Ustochreptic Calciorthids. These soils are similar to Laguna soils. The difference is mainly due to a less effective precipitation. Surface horizons of Quintana soils do not have the buildup of organic matter, therefore, are lighter in color over those of Laguna soils. The moisture stress pointed out for Laguna soils is apparent with these soils.

Within the study area Quintana soils are the most restricted in their capacity to produce vegetation by a limited effective precipitation. The high alkaline-earth content throughout the soil profile tends to cause a physiological drought in some plants. The combination of low effective precipitation and the physiological drought seriously limits the capacity of this soil to produce vegetation.

I. Summary of Soil Productivity

The capacity to produce vegetation is set by the most limiting factor. The relationships valid for this study area are shown in Table 6.

It would appear from this study that the potential to produce vegetation at the upper elevations is limited by low heat and at the lower elevations by a moisture deficiency. Within each of the potential natural vegetative separates, it is inherent soil fertility that is the limiting factor for plant production. This is observed in the case of Laguna and Chimayo soils. The Chimayo soils (a member of the loamy-skeletal, mixed, nonacid, mesic family of Typic Ustorthents) would have greater restrictions relating to production of vegetation than Laguna soils (a member of the loamy-skeletal, mixed, mesic family of Ustochreptic Calciorthids). Both soils would exhibit undesirable soil-moisture relationships, but the greater restriction would be associated with the Lithic Ustorthent.

Table 6 — Soil Productivity

Soil Series	Soil Moisture Regime	Soil Temperature Regime	Inherent Fertility*	Production Capacity**
Quintana	Ustic	Mesic	7	6
Laguna	Ustic	Mesic	6	5
Chimayo	Ustic	Mesic	8	8
Mirabal	Ustic	Frigid	5	4
Hyde	Udic	Frigid	3	2
Medio	Udic	Cryic	2	1
Nambe	Udic	Cryic	4	3
Penitente	Udic	Pergelic	1	7

* Inherent fertility as rated here is a relative rating with number one being the least restrictive and number eight having the highest restriction. This rating is based on characteristics, pointed out in the main text, that can be measured in the field and related to the SOIL TAXONOMY.

** This is a relative rating since production capacity is a function of inherent fertility and environmental conditions (temperature, light, precipitation, slope, and drainage). Overall productivity is influenced by landscape pattern along with shape, size, and kinds of soils and their arrangement together. This rating considers only soil moisture/temperature and inherent soil fertility and at a level reflected within the SOIL TAXONOMY. Number one indicates the highest capacity to produce vegetation while number eight the lowest capacity to produce vegetation.

Conclusions

1. Soil moisture and soil temperature regimes identified in this study can be correlated with potential natural vegetation:

Potential Natural Vegetation	Indicator Plants	Soil Moisture Regime	Soil Temperature Regime
Juniper-Pinyon Woodland	One-seed juniper Pinyon pine	Ustic	Mesic
Pinyon-Juniper Woodland	Pinyon pine One-seed juniper Rocky Mtn. juniper *Ponderosa pine	Ustic	Mesic
Ponderosa Pine Forest	Ponderosa pine	Ustic	Frigid
Douglas Fir-Ponderosa Pine Forest	Douglas fir Ponderosa pine White fir *Quaking aspen *Limber pine	Udic	Frigid
Douglas Fir-Engelmann Spruce Forest	Douglas fir Engelmann spruce White fir Corkbark fir *Quaking aspen	Udic	Cryic
Engelmann Spruce Forest	Engelmann spruce Corkbark fir	Udic	Cryic
Alpine	*Absence of trees* Sedges Fescues Bluegrass Bentgrass	Udic	Pergelic

*usually scattered

2. Correlation of potential natural vegetaion with soil moisture and soil temperature regimes allows the soil scientist to circumvent the problem of relating complex environmental data directly to soils. Realistically this sets moisture and temperature limits, which can be related to soil genesis and morphology, on logical separations that can be easily identified and managed as an entity. With this approach one can consistently separate these regimes to reproduce and interpret the soil survey with parallel accuracy.

3. The *parameter limits* of the various potential natural vegetation separates of the study area are set mainly by a combination of moisture and temperature. The *capacity* to produce vegetation biomass can be related as a function of soil moisture, soil temperature, and soil fertility. Any one of these may be the limiting factor for total production of vegetation. Further influence of the overall capacity to produce vegetation is set by environmental

constraints such as slope, topography, drainage, soil patterns, etc., and must be considered in actual production ratings.

4. Interruption of climax vegetation within the Alpine and Engelmann Spruce-Fir Forest can lead to serious related management problems. This is measured as a significant change in associated soil temperature and soil moisture regimes and manifested in serious soil erosion.
5. Often the correlation between complex plant-environmental relationships and complex soil-environmental relationships are not clear cut. This is attributed in part to the degree of difficulty in obtaining correlating information (soil moisture measurements), the level of correlation that is valid or the added complexity of an environment associated with transitional vegetative associations.
6. With parent material source held constant, the broad correlation between environment (moisture and temperature) and soil genesis and morphology can be observed within the study area. These relationships are reflected within the SOIL TAXONOMY.
7. Interpretations correlate at various important levels with soils as separated by the SOIL TAXONOMY. Table 7 illustrates this correlation.
8. It is more practical to recognize the influence of environmental factors such as temperature and moisture on the potential natural vegetation and relate these to soil moisture and soil temperature regimes than to simply prove the existence of the technical soil moisture and soil temperature regimes as defined in the SOIL TAXONOMY. Once these environmental factors that relate to potential natural vegetation have been recognized, they can be fitted into the defined soil temperature and soil moisture regimes.
9. Both short-range and long-range management practices are influenced by the natural vegetative separates, their characteristic environment (temperature and moisture), as well as inherent soil fertility.

Table 7 — Summary of Interpretations

Soil Series and Soil Classification	Soil Moisture Regime	Soil Temperature Regime	Inherent Fertility	Vegetative Production Potential	Potential Natural Vegetation	Interpretations Dealing with Constraints Related to the Following Tree Species: Pinyon Pine	One-seed Juniper	Ponderosa Pine	Douglas Fir	White Fir	Aspen	Corkbark Fir	Engelmann Spruce
Quintana Ustochreptic Calciorthid loamy-skel., mixed, mesic	Ustic	Mesic	7	6	Juniper-Pinyon Woodland	X	X						
Laguna Ustollic Calciorthid loamy-skel., mixed, mesic	Ustic	Mesic	6	5	Pinyon-Juniper Woodland	X	X						
Chimayo Lithic Ustorthent loamy-skel., mixed, nonacid, mesic	Ustic	Mesic	8	8	Pinyon-Juniper Woodland	X	X						
Mirabal Typic Ustorthent loamy-skel., mixed, nonacid, frigid	Ustic	Frigid	5	4	Ponderosa Pine Forest			X					
Hyde Typic Dystrochrept loamy-skel., mixed, frigid	Udic	Frigid	3	2	Douglas Fir-Ponderosa Pine Forest			X	X	X	X		
Medio Dystric Cryochrept loamy-skel., mixed	Udic	Cryic	2	1	Douglas Fir-Engelmann Spruce Forest				X	X	X	X	X
Nambe Dystric Cryochrept loamy-skel., mixed	Udic (Perudic)	Cryic	4	3	Engelmann Spruce-Fir Forest							X	X
Penitente Pergelic Cryumbrept loamy-skel., mixed	Udic	Pergelic	1	7	Alpine				N O N E				

Implications for Further Research

This study was seriously hindered by several extraneous factors. These include time limitations, budgetary limitations, lack of trained manpower, and lack of sophisticated equipment for measuring soil moisture/temperature. In lieu of field procedures, subsequent studies should employ laboratory methods for the characterization of the soils.

A broader study area should be examined in order to coordinate the numerous potential natural vegetation separates with soil temperature/moisture regimes. A range from hypothermic to pergelic, from aridic to udic, should be studied. There should be an applied research project dealing with this study within the soils program so that it can be coordinated with the present soil resource inventory.

Operational Definition of Terms

1. Climosequence. The various soil properties discussed in relation to moisture and temperature regimes form a continuous pattern over the landscape. (Buol, Hale, and McCraken, 1973)
2. Potential natural vegetation. The vegetation that would exist today if man were removed from the scene and if resulting plant succession were telescoped into a single moment. (Kuchler, 1964)
3. Climax vegetation. The final or stable community in a developmental series (sere); it is self-perpetuating and in equilibrium with the physical habitat. (Odum, 1971)
4. Effective precipitation. That portion of precipitation that enters the soil profile and is not lost to evapo-transpiration.
5. Water balance. A theoretical model that depicts moisture accretion and depletion. (SOIL TAXONOMY, 1973)

Appendix

En Erratum

Throughout this paper Laguna and Quintana soils are classified within the SOIL TAXONOMY as Calciorthids. Technically they do not meet one part of the standard criteria; conductivity of the saturated extract of 2 mmhos per cm at 25°C.

These soils would have been classified as Ustochrepts except they do not meet the criteria of this class. The intent of the Typic Ustochrepts is to separate out soils under higher precipitation than Laguna or Quintana soils.

It is the authors' opinion that Laguna and Quintana soils best fit the intent of the Ustollic and Ustochreptic Calciorthids. Perhaps the criteria of 2 mmhos per cm at 25°C should be reduced to 1 mmhos per cm at 25°C. An alternative would be to give greater emphasis to the alkaline-earth content when separating Calciorthids.

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ADDENDUM

CLIMOSEQUENCE STUDY OF THE MOUNTAINOUS SOILS ADJACENT TO SANTA FE, NEW MEXICO

A comparison of Table 3 (study year 1973-74) and Table 3 (study year 1974-75) indicates the following:

1. Observable trend through colder average annual soil temperatures (most prevalent among lower elevational soils).

2. Observable trend through warmer average summer soil temperatures in all cases except site 35 which remained the same.

3. Highest range between average annual soil temperatures was 3.6 F at site 11.

4. Highest range between average summer soil temperatures was 7.9 F at site 4.

5. Majority of the average annual soil temperatures differed from the previous year by 2.2 F or less.

A comparison of Table 4 (study year 1973-74) and Table 4 (study year 1974-75) indicates the following:

1. Snow pack depths were at maximum in April of this study year as opposed to February of the previous year.

2. Maximum snow pack depths were approximately twice those of last year.

On the basis of the data for this study year the soils at sites 4, 14, and 25 could be classed as frigid. Sites 14 and 25, are within 2°F of meeting criteria for a cryic soil temperature regime (average summer soil temperature less than 47°F and average annual greater than 32°F). Site 4 is only 0.2°F outside this range. Site 4 is representative of a seral stage of the Engelmann Spruce - Fir Forest therefore lacks the modifying effect of canopy cover. Site 14 is representative of a seral stage of the Douglas Fir - Engelmann Spruce Forest. The aspen canopy has a modifying effect on the soil temperatures but not to the degree that a conifer stand would. Site 25 is representative of the lower elevational limits of Medio soils manifesting a borderline cryic/frigid regime. Therefore, these three sites should still be classed as cryic.

Site 17 should be recognized as representative of a Engelmann Spruce - Fir - Aspen Forest. This site is within a climatic zone that normally lies between the Douglas Fir - Engelmann Spruce Forest and the Engelmann Spruce - Fir Forest. The aspen competes with conifers in this environmental niche that allows it to always be present under natural conditions.

TABLE 3. SOIL TEMPERATURES - JUNE 1974 THROUGH MAY 1975

Soil Series	Site No.	June 1974	July 1974	Aug. 1974	Sept. 1974	Oct. 1974	Nov. 1974	Dec. 1974	Jan. 1975	Feb. 1975	Mar. 1975	Apr. 1975	May 1975	Avg. of June, July, August	Avg. Yearly	Soil Temp. Regime
Penitente	1	40.5	43.5	44.5	43.1	35.2	32.2	24.7	18.6	18.6	22.6	21.7	30.7	42.8	31.3	Pergelic
Penitente	2	43.9	45.3	47.7	46.7	38.7	32.4	22.9	17.6	20.1	21.7	21.5	30.7	45.6	33.3	Cryic
Nambe	35	31.2	38.5	40.7	40.3	35.8	33.3	31.8	31.4	31.4	31.6	31.4	31.4	36.8	34.1	Cryic
Nambe, eroded	3	37.7	42.6	44.3	42.8	36.4	32.4	28.5	21.2	22.2	25.0	24.5	30.0	41.5	32.3	Cryic
Nambe, eroded	4	46.7	49.6	51.4	50.0	41.9	34.8	30.7	30.3	30.5	--	31.2	31.4	*49.2	38.9	Cryic
Nambe	9	35.6	40.5	41.5	40.5	36.6	33.9	32.0	31.2	30.9	31.6	31.2	31.2	39.2	34.7	Cryic
Nambe	5	38.5	43.1	43.7	43.5	38.7	35.0	30.5	29.6	30.0	30.9	30.7	31.2	41.8	35.4	Cryic
Nambe	7	42.8	46.9	47.9	47.3	40.3	34.6	30.5	29.4	29.4	30.7	30.7	31.2	45.9	36.8	Cryic
Nambe	17	39.7	44.3	45.5	42.8	38.3	33.7	30.9	30.3	29.8	30.7	30.5	31.2	43.2	35.6	Cryic
Medio	14	46.3	48.3	50.4	48.5	44.1	37.7	33.7	32.7	32.2	32.4	--	38.3	*48.3	40.4	Cryic
Medio	13	41.5	45.9	47.3	46.1	41.5	36.2	32.9	32.2	33.9	32.2	31.8	31.8	44.9	37.8	Cryic
Medio	24	41.5	44.7	46.3	45.3	42.1	35.6	31.4	30.9	30.9	31.2	31.6	38.5	44.2	37.5	Cryic
Medio	29	41.1	45.9	45.9	44.1	40.1	34.1	31.4	30.3	30.0	30.7	30.5	31.4	44.3	36.3	Cryic
Medio	27	43.7	48.3	48.7	46.9	42.6	35.2	31.4	30.3	30.5	31.4	31.4	31.6	46.9	37.7	Cryic
Medio	25	44.5	49.1	49.5	47.9	43.3	35.2	30.7	29.8	29.8	31.2	31.6	35.2	*47.7	38.1	Cryic
Hyde	22	52.6	52.7	55.2	52.9	47.9	41.7	35.2	33.7	33.5	33.5	32.7	47.7	53.5	43.2	Frigid
Hyde	36	46.9	50.0	51.6	50.2	45.3	38.9	34.4	33.3	32.9	33.1	33.1	41.1	49.5	40.9	Frigid
Hyde	12	47.5	51.0	51.8	50.2	44.9	36.2	32.4	31.6	30.9	32.0	31.8	37.2	50.1	39.8	Frigid
Hyde	16	47.5	50.6	51.0	48.5	43.5	34.8	30.7	30.5	30.7	31.6	31.8	39.1	49.7	39.2	Frigid
Hyde	10	54.1	56.0	57.0	53.9	47.3	37.2	30.7	29.9	30.3	31.8	32.2	43.5	55.7	42.0	Frigid
Mirabal	8	49.5	52.0	53.5	53.3	47.9	42.3	36.2	33.9	33.9	34.6	35.0	43.0	51.7	42.9	Frigid
Mirabal	19	58.1	58.1	59.3	55.8	48.9	41.9	34.4	33.3	34.6	35.6	35.6	50.8	58.5	45.5	Frigid
Mirabal	20	50.4	52.9	53.1	50.6	45.5	36.8	32.0	31.8	31.6	32.4	32.4	40.5	52.1	40.8	Frigid
Chimayo	21	63.3	62.5	64.6	60.2	51.0	43.1	34.8	33.9	34.6	37.0	40.1	54.7	63.5	48.3	Mesic
Chimayo	11	63.2	60.2	64.5	59.9	49.6	46.7	37.2	34.4	37.7	36.4	39.6	54.5	62.6	48.6	Mesic
Laguna	18	55.4	57.8	58.3	63.9	47.1	35.4	30.3	28.8	29.6	31.8	32.0	46.1	57.2	43.0	Frigid
Chimayo	15	65.8	53.1	67.9	61.4	52.0	46.3	37.0	34.4	37.7	38.7	43.0	58.3	62.3	49.6	Mesic
Quintana	30	70.2	67.3	71.9	63.7	52.7	38.1	31.4	30.0	31.2	36.4	43.3	61.4	69.8	49.8	Mesic
Quintana	26	71.0	68.3	74.1	67.9	57.4	50.8	39.7	35.2	40.5	43.0	47.1	62.7	71.1	54.8	Mesic

Measurements taken around 15th of each month.

*Within 2°F of meeting criteria for cryic; therefore, classed as cryic.

TABLE 4. SNOW DEPTH MEASUREMENTS AT SOIL TEMPERATURE SITES

Soil Series	Site No.	June 1974	July 1974	Aug. 1974	Sept. 1974	Oct. 1974	Nov. 1974	Dec. 1974	Jan. 1975	Feb. 1975	Mar. 1975	Apr. 1975	May 1975
						(inches)							
Penitente	1	0	0	0	P-1	P-1	12	4	2	2	3	4	0
Penitente	2	0	0	0	P-1	P-5	4	2	3	8	2	1	0
Nambe	35	0	0	0	P-1	2	12	15	42	48	66	72	48
Nambe, eroded	3	0	0	0	0	P-1	7	7	3	2	12	18	0
Nambe, eroded	4	0	0	0	0	0	8	7	39	72	120	120	84
Nambe	9	0	0	0	0	P-1	12	12	30	42	48	72	36
Nambe	5	0	0	0	0	P-1	10	10	30	42	60	66	36
Nambe	7	0	0	0	0	0	6	4	12	30	48	60	P-18
Nambe	17	0	0	0	0	0	7	9	18	24	54	60	30
Medio	14	0	0	0	0	0	0	2	10	8	24	12	0
Medio	13	0	0	0	0	0	6	12	24	36	48	48	P-10
Medio	24	0	0	0	0	0	6	9	18	18	36	48	P-12
Medio	29	0	0	0	0	0	4	6	18	15	42	48	12
Medio	27	0	0	0	0	0	2	6	12	15	36	36	P-10
Medio	25	0	0	0	0	0	P-1	2	7	8	12	18	P-6
Hyde	22	0	0	0	0	0	0	0	P-4	P-2	7	0	0
Hyde	36	0	0	0	0	0	0	P-2	10	8	10	3	0
Hyde	12	0	0	0	0	0	P-1	2	8	7	12	18	0
Hyde	16	0	0	0	0	0	0	P-1	8	4	10	2	0
Hyde	10	0	0	0	0	0	0	P-1	2	3	4	2	0
Mirabal	8	0	0	0	0	0	0	P-1	P-1	P-4	P-2	0	0
Mirabal	19	0	0	0	0	0	0	P-1	P-2	0	0	0	0
Mirabal	20	0	0	0	0	0	0	P-1	5	4	2	P-2	0
Chimayo	21	0	0	0	0	0	0	0	2	0	0	0	0
Chimayo	11	0	0	0	0	0	0	0	0	0	0	0	0
Chimayo	15	0	0	0	0	0	0	0	0	0	0	0	0
Laguna	18	0	0	0	0	0	0	1	7	6	4	0	0
Quintana	30	0	0	0	0	0	0	P-1	6	P-6	0	0	0
Quintana	26	0	0	0	0	0	0	0	P-1	0	0	0	0

P - Patchy